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Chemostratigraphy of potassic sedimentary rocks in Gale crater, Mars, as seen by ChemCam onboard Curiosity

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Abstract

The analysis of the sedimentary record on Aeolis Palus reveals the occurrence of rocks showing a significantly enhanced K content at Cooperstown and Kimberley. Ranging between massive and cross-bedded fine to very coarse sandstones, and conglomerates, those rocks are inferred to represent fluvial or fluvio-deltaic depositional environments and derive from basalt and potassic sources, essentially unweathered.

1. Introduction

The Mars Science Laboratory (MSL) rover Curiosity encountered potassic sedimentary rocks along its traverse to Mount Sharp. Those rocks have been analyzed by the ChemCam instrument that combines a Laser-Induced Breakdown Spectroscopy (LIBS) instrument [1, 2] and a Remote Micro-Imager (RMI) [3] at two waypoints informally named Cooperstown (sols 438 to 453) and Kimberley (sols 576 to 632). Here, we report a synthesis of the chemical composition of the potassic rocks as seen by ChemCam according to their stratigraphic unit and facies at Cooperstown and Kimberley.

2. Stratigraphy and rock facies

The potassic rocks are primarily associated with two geomorphological units defined from orbit: a light-toned topographically variable, or "Rugged Unit"; and overlying light-toned striated rocks forming a "Striated Unit" [4] (***Fig. 1***). Cooperstown (-4.62°N, 137.42°E) is associated with the Rugged Unit and is topographically above the Yellowknife Bay Formation (YKB) investigated during the first phase of the mission [4]. Two members of the Cooperstown formation have been investigated by ChemCam and correspond to massive fine and coarse sandstones (***Fig. 1A***). The Kimberley formation (-4.64°N, 137.4°E) is associated with both the Rugged Unit and

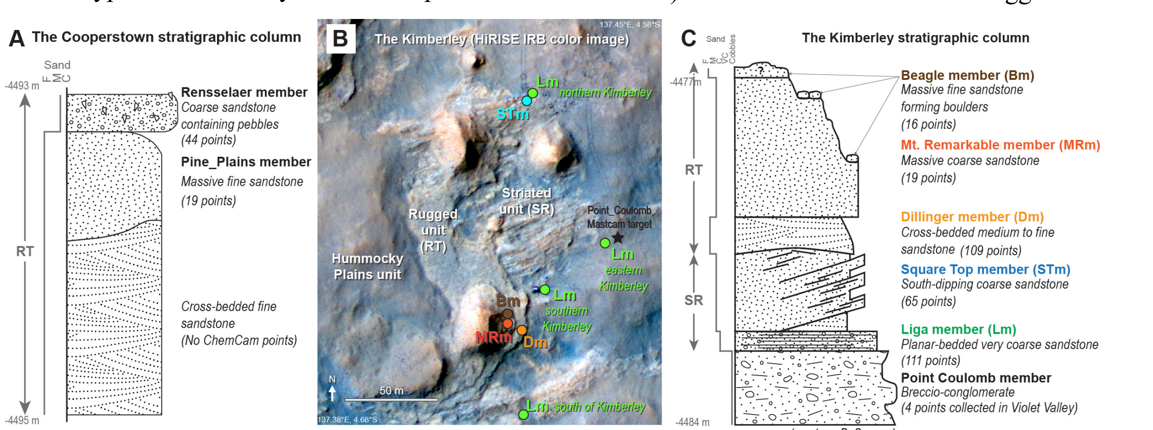
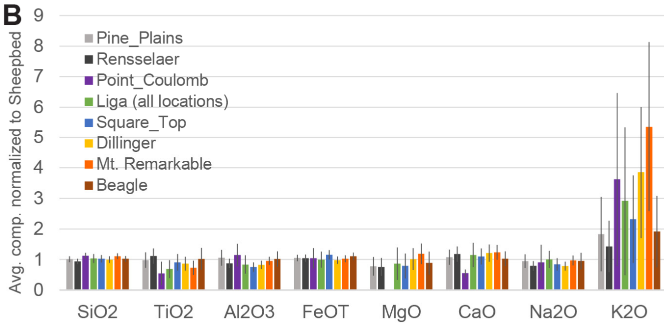


Fig. 1: *Stratigraphy and facies of the potassic sedimentary rocks. Thicknesses of the stratigraphic columns are not to scale. Elevations have been estimated by K. Stack [5]. The number of points indicated refers to the number of ChemCam points collected for each member and located in Fig. 1B for the Kimberley formation.*

A

Formation	Member (# *of points*)	SiO_2	TiO_2	Al_2O_3	FeO_T	MgO	CaO	Na_2O	K_2O	Total
Cooperstown	Pine_Plains (*44*)	46.6	1.1	8.6	17.8	4.8	6.8	2.3	1.1	89.0
	Rensselaer (*19*)	43.6	1.2	7.1	17.6	4.6	7.4	1.9	0.9	84.3
Kimberley	Point_Coulomb (*4*)	52.1	0.6	9.3	17.6	0.0	3.5	2.2	2.2	84.6
	Liga (*114*)	48.0	0.8	6.8	16.8	5.3	7.2	2.4	1.8	89.0
	Square_Top (*65*)	47.5	1.0	6.1	19.6	4.8	6.9	2.0	1.4	89.4
	Dillinger (*109*)	46.1	1.0	6.7	16.6	6.2	7.6	1.9	2.3	88.4
	Mt. Remarkable (*19*)	51.3	0.8	7.8	17.4	7.2	7.8	2.3	3.2	97.8
	Beagle (*16*)	47.4	1.1	8.2	18.7	5.2	6.5	2.3	1.2	90.6
YKB	Sheepbed (*482*)	46.2	1.1	8.1	16.9	6.1	6.3	2.4	0.6	87.6
	RMSEP	7.1	0.55	3.7	4	3	3.3	0.7	0.9	10.1



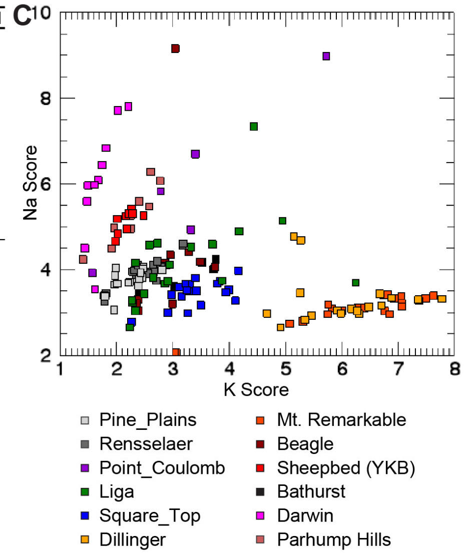


Fig. 2: *Major-element composition of the potassic sedimentary rocks analyzed by ChemCam. (**A**) Average composition (wt%) of each member determined by PLS. Drill tailings, soils and Mn-rich targets are not taken into account in the average composition of the Dillinger member. (**B**) Average composition of the potassic rocks normalized to Sheepbed (YKB). Error bars are standard deviation of the compositions and primarily reflect heterogeneity within each member. (**C**) ICA score plot of K component versus Na component. Sheepbed, Bathurst, Darwin and Parhump Hills targets are indicated for reference.*

the Striated unit, and it can be subdivided into seven members corresponding to massive and cross-bedded fine to very coarse sandstones, and conglomerates (***Fig. 1B-C***). These rock facies point to fluvial or fluvio-deltaic depositional environments [5-7].

3. Chemical composition

The sedimentary rocks of the Cooperstown and Kimberley formations have a basaltic-like composition according to Partial Least Squares (PLS), a multivariate regression method [8] (***Fig. 2A***). Those sedimentary rocks primarily differ in composition from the previously encountered sedimentary rocks in YKB or the conglomerates in Darwin [9] by their significantly higher content in K_2O (***Fig. 2B***). The Dillinger and Mt. Remarkable members (Kimberley) in particular display the strongest enrichments in K (***Fig. 2A***). An Independent Component Analysis (ICA) [10] reveals that the Na/K ratio of the Dillinger and the Mt. Remarkable members is much lower than for the other members (***Fig. 2C***). The K-feldspar and phyllosilicates (illite and/or smectite) identified in the Dillinger member by CheMin [11-12] are consistent with this enrichment in K. Overall the K abundance gradually increases between the Cooperstown and the Kimberley formations and between the Striated Unit and the Rugged Unit in the Kimberley Formation, which suggests an increasing contribution of a potassic source rock. ChemCam analyses also reveal high contents in F, Li [13], Zn [14] in the bulk rock of the Kimberley Formation, and in Mn-rich fracture fills [15] suggesting that alteration processes, possibly pre- and post-depositional, may have contributed to the enrichment in K. However, all of these rocks display a low CIA (Chemical Index of Alteration) with CIA ≤ 46, except for Point_Coulomb. It indicates a rather limited chemical weathering prior to deposition and supports a primarily detrital origin for the enhancement in K.

Acknowledgements

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